

CHEMONICS INTERNATIONAL INC.



***Appropriate Technology Cold Store Construction and  
Review of Post-harvest Transport and  
Handling Practices for Export of Fresh Produce from Rwanda***

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## EXECUTIVE SUMMARY

Four Evaporative Coolers for the storage of fresh produce were constructed for ADAR clients in Rwanda. The sites for cooler construction were: Nyirangarama (where there is a passion fruit exporter), Butare at the National University of Rwanda farm, Kinamba-Kigali (for a fruit exporter) and Kibungo (for a banana exporter). The coolers were constructed using locally available materials. The main frame was made from timber and the walls from charcoal held in by wire netting. The roof was made from grass or clay tiles and the floor from cement or brick. When tested the temperature inside the cooler was found to be 7 °C lower than the outside temperature, which is well within the expected range since the effectiveness of this type of cooler is governed by environmental conditions. The coolers therefore have the potential to be useful for reducing deterioration of fresh produce, which is especially important for that destined for export markets.

The current handling and transport practices for passion fruit exports were assessed and the major problems observed included fruit damage (especially bruises, scratching of the peel and fruit splitting ) in part arising from inappropriate harvest/transport containers. Some of the fruit rejected during grading were already starting to shrivel, which is an indication of poor storage conditions. Other problems originated in the field, including diseases and fruit scarring, both of which made the fruit unacceptable for export. Since the grading system is labour intensive, it needs to be more efficient for a higher output with each worker making less decisions but processing more fruit. Worker comfort is also important for speeding up the process. Fruit arriving from the field needs to improve in terms of quality and issues like disease control need to be addressed. Packaging is very important in reducing damage to produce and the large sacks commonly used to carry fruit should be discouraged and wooden crates promoted. Good handling throughout the chain is important and simple practices like keeping produce in shade at all times would be very effective in reducing deterioration, thereby increasing the packout rate.

# 1. CONSTRUCTION OF CHARCOAL EVAPORATIVE COOLER

## 1.1 Introduction

The Evaporative Cooler is designed to provide an environment which is both lower than ambient temperature and at a higher level of relative humidity for the storage of fresh produce. It works on the principle of a porous structure to which water is added; as air flows across this “wet wall” the air temperature is decreased due to the loss of heat through the evaporation of water. The temperature is normally lowered by about 5 to 10 °C, depending on the relative humidity of the ambient air. Evaporative Coolers can be used for all types of produce but subtropical fruits respond best because their optimum storage temperatures are closer to those achieved by Evaporative Coolers. Various designs of Evaporative Coolers have been used in different parts of the world; the design employed in Rwanda was selected as being suitable for the conditions prevailing. The construction and materials employed in Rwanda can serve as guidelines, and modifications can be made as needed.

## 1.2 Design

The design of the Evaporative Cooler is as shown in Figure 1. The cooler is basically a small room with charcoal walls. Charcoal was selected because it has a very porous structure that can hold water and is a material which is easily found in Rwanda. The structure has a wooden frame which supports the walls and roof. The charcoal walls are constructed from a wooden frame covered with wire mesh separated by about 10 cm with the interior being filled with charcoal. The charcoal walls are on all four sides, filled up to the top 15 to 20 cm below the roof, with this space being left open so as to allow air circulation.

The cooler has a door for security purposes and the roof should be made preferably with thatch or other material that provides a cool shade. The floor can simply be bare ground that is compacted, however a more durable floor such as cement or bricks is more durable. The use of wooden pallets on the floor is advisable as this will keep produce off the ground, reducing the likelihood of infection of produce with soil borne diseases, and molds in general.

Dimensions: The dimensions of the cooler are 2.0 m long x 1.5 m wide and 2.0 m high. The cooler has a slanting roof, the angle between the front and rear of the cooler being adjusted to accommodate the type of material employed for the roof. Use of tiles requires the roof to be steeper with a height of 2.6 m for the

front (for a height of 2 m at the rear of the structure).

If thatching is used for a cover, the height can be lowered to 2.2 m for the front and 1.8 m for the rear of the structure. The capacity of the cooler is approximately 600 to 800 kg of fresh produce.

### **1.3. Site Selection**

The site on to which a cooler is to be built should be considered carefully. Evaporative Coolers rely on air movement in order to be effective, thus coolers should not be placed in locations which receive little or no wind. A great deal of water is required to render the cooler operational and so the site should have a good source of water close by. The cooler will mainly be used for storing fresh fruits and vegetables and so the site should be accessible to producers of fresh produce. A shady location should also be considered because fruit are not exposed to direct sun before going into the cooler and so they can reach a lower temperature much sooner. Shady sites also result in lower water requirements for the operation of the cooler (i.e. the charcoal walls can be wetted less frequently\do not dry out as quickly).

### **1.4 Main Frame**

The construction of the cooler can be conducted in stages, starting with the main frame. The ground should first be cleared if there is grass or rubble before putting in the main frame. This can be made from wooden poles approximately 10 cm diameter. Eucalyptus poles were used as they are widely available. Four poles are needed, one for each corner of the room. A fifth pole is used to provide a support for the door and the distance to the next pole depends on the size of the door (Diagram 2). The poles are fixed directly into the ground using holes 40 – 50 cm deep. If termites are a problem, the ends of the poles should be treated with a preservative or insecticide or used engine oil. The soil around each pole should be well compacted so that the pole is firmly anchored.

## 1.5 Charcoal Walls

The charcoal walls are constructed from timber and wire netting. The poles of the main frame act as vertical ends of the walls. Horizontal wooden strips (parallel to one another) on either side of these poles are attached at regular intervals going up the poles so as to create a frame for a wall with the width of the poles (or approximately 10 cm). The wood strips used should be sawn timber with dimensions of 25 mm x 40 mm, as this size of timber is easier to work with. These wooden strips facilitate the fixing of the wire mesh since this can be nailed tightly to the wood which is at the bottom, middle and top of the wall. The distance between the wood strips up the poles is about 80 cm which is about the width of the wire mesh, which makes attaching the fence easier. Additional strips of wood can be used if needed for strengthening the wall or preventing the charcoal from sagging. This frame (including all the poles and roofing timber) should then be painted with a good quality paint such as oil paint to protect the wood from water.

The inside strips of timber may cross each other at the corners. In order to make a tidy and even intersection, notches can be cut out of the timber at the point where they will cross and they can then be fitted together to make an interlocking join (see Photograph 2). The two wooden strips running parallel can be kept at a uniform distance apart by fixing a 10 cm wide block between them at the halfway point. This will strengthen the frame and reduce bulging or warping (see Photograph 3).

This frame is then covered with a wire mesh on all sides except the top which should be kept open for filling in with charcoal. The wire mesh is attached to the wooden frame using nails. The bottom portion of the walls may also be covered with wire or can be filled in with material such as stones that both allow good drainage and prevent the charcoal from spilling out from the walls. It is important to ensure that the wire is pulled tightly before nailing it so that the wall keeps its shape and the walls do not bulge when they are filled with charcoal.

Soft wire, tied to both sides of the wire mesh at regular intervals (e.g. every 20 cm) is recommended to hold the two sides together and prevent the charcoal from settling to the bottom which results in the walls bulging. The frames should then be filled with charcoal. During the filling process the charcoal should not be compressed or packed down because this will reduce air movement across the wall.

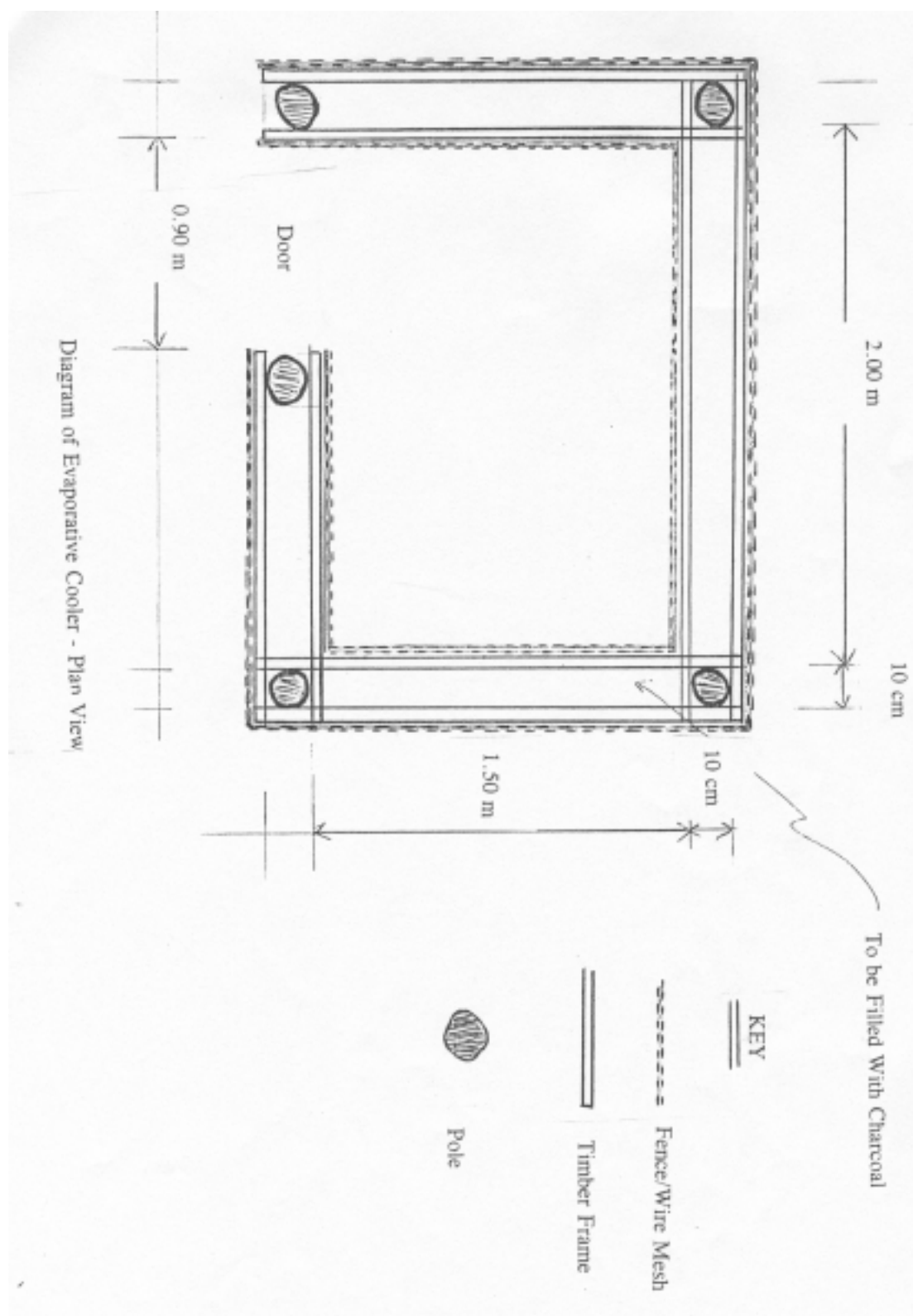
## **1.6 Roof, floor and door**

The roof can be constructed from a plastic sheet over which is placed a thatch made from materials such as grass or banana leaves. The plastic is to protect the interior from heavy rain. An alternative is to use clay tiles, placed over the plastic sheeting; this type of roof should be more durable and provide greater protection from heavy rains.

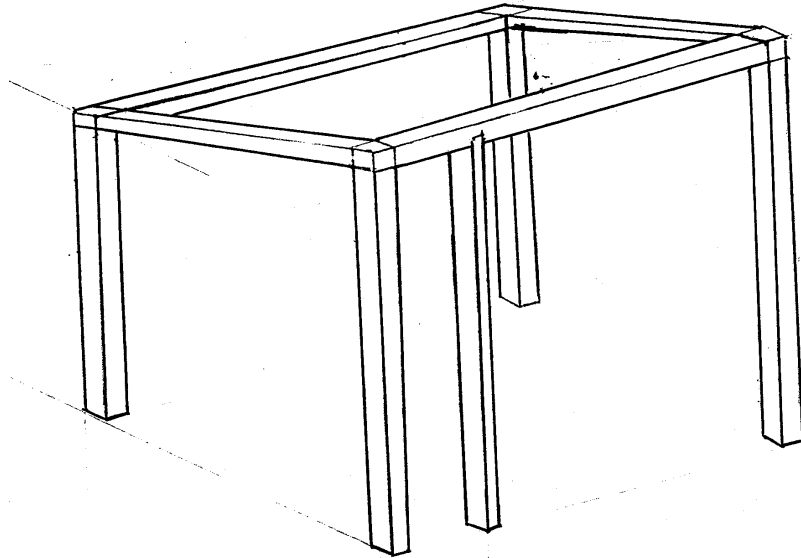
The floor can simply be a compacted earth floor; however a more durable floor (e.g. of bricks or cement) can be constructed if the cooler is located in an area which receives heavy rainfall. Wooden pallets should be placed on the floor once the floor has been completed. It is a good idea to provide a drainage channel away from the cooler to remove excess water that may accumulate during wetting of the walls.

The door should be fitted so that it opens outwards. This will prevent wasting of interior space that can be used instead for storage of produce. It is a good idea to put a lock on the door for security purposes.

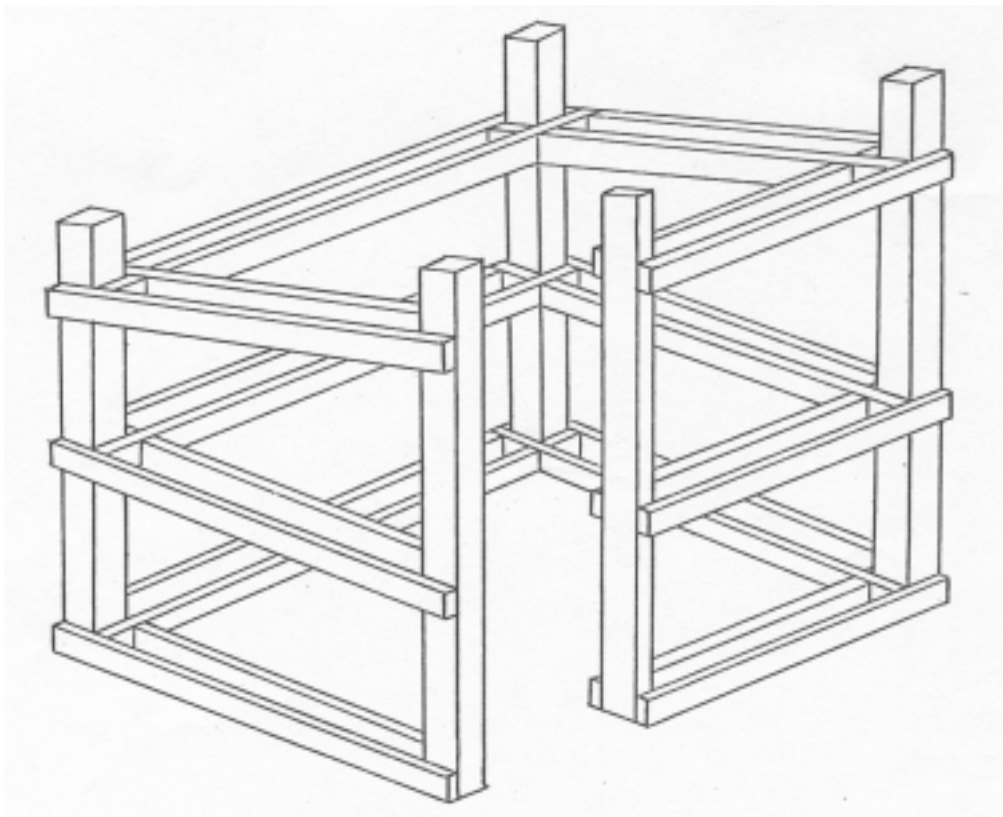




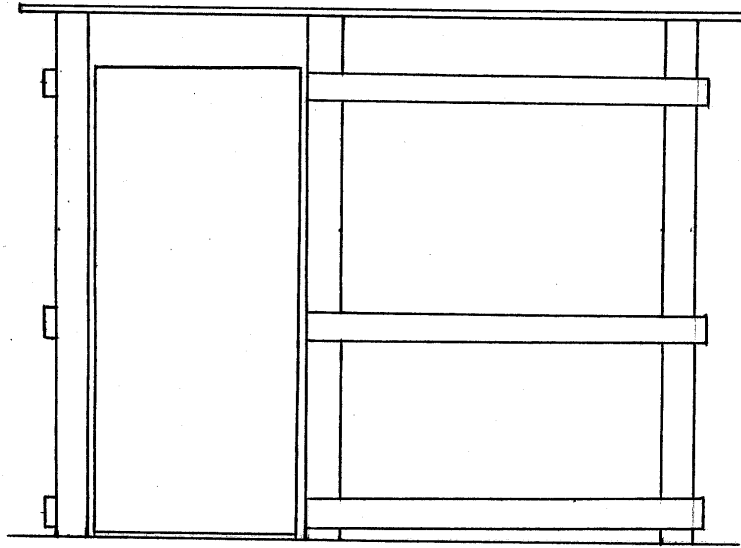
**Diagram 1.** Plan (overhead) view of Evaporative Cooler



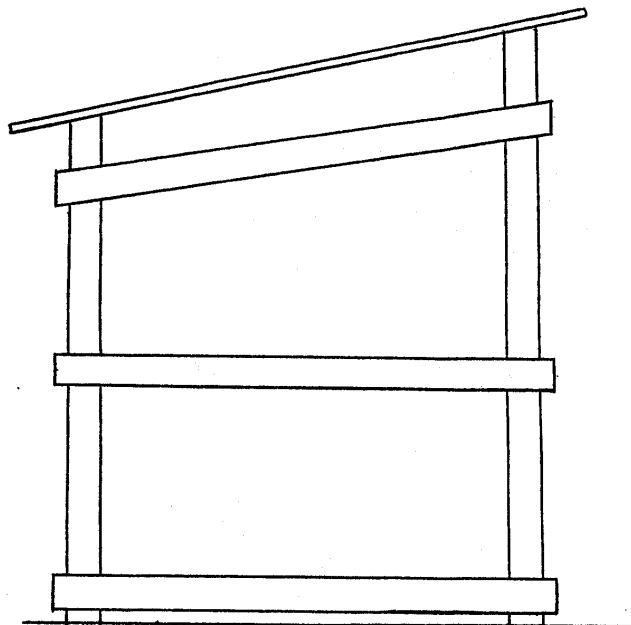
**Diagram 2.** Outer timber frame for Evaporative Cooler



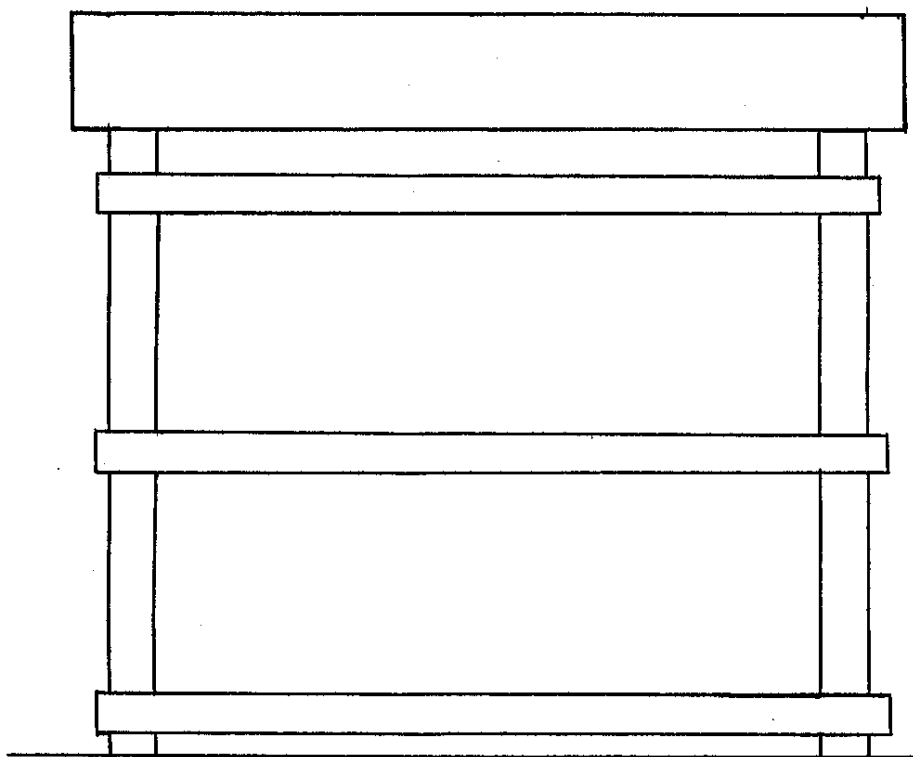
**Diagram 3.** Details of Timber Frame for Charcoal Wall and Roof



**Diagram 4. Front view of Evaporative Cooler**



**Diagram 5. Evaporative Cooler - Side View**



**Diagram 6.** Evaporative Cooler - Rear View

## 1.7. Testing and Modifications

Once the cooler is completed it will need to be tested so that the best method of operation can be worked out. The first requirement is that charcoal walls should be wetted completely by applying water to excess on the first day. Water can be applied every two hours to the point of runoff. This is important because it enables fine particles to be washed out and the charcoal will then be able to hold more or retain more water. The water should be applied to the top of the wall so that it flows downwards through the charcoal wall.

The cooler can then be tested to work out how much water to apply to the walls and the frequency of application. The walls should be wetted with water until the water is about to start dripping. This quantity of water should be noted. The walls can then be observed to note how long they take to dry out. The temperature and humidity can also be checked to find out the extent of the drop in temperature and increase in percent relative humidity.

A wetting cycle can then be worked out for example wetting can be carried out once in the morning and once in the evening. If this results in the walls drying out significantly then the walls may need to be wetted around midday. It is important to note that this cycle will vary depending on the prevailing weather conditions. It may be necessary to apply water more frequently if the charcoal walls are drying out rapidly.

The cooler should also be tested to find out if any modifications need to be made. It is better for modifications to be made before the cooler is put into use but changes can also be made later in the usage of the cooler. If the temperature drop is insignificant or the increase in humidity is minimal then it may be necessary to modify the cooler. The possible modifications include -

- a) Closing off the open spaces or reducing the open gaps with e.g. plywood sheeting or increasing the height of the charcoal wall. This means air coming in to the cooler is made to go through the charcoal walls
- b) Placing a wind driven ventilator on the roof. This device will suck air in the cooler out and will increase air movement through the charcoal walls.

Other modifications allow for more efficient utilization of the cooler. A reservoir can be placed on the roof of the cooler with a pipe leading across the top of the charcoal walls. If the pipe has small holes that allows slow dripping of water then the walls will receive constant water and will keep cooling the air.

## **1.8. Operation of the Evaporative Cooler**

The Evaporative Cooler is used to keep produce at a temperature that is lower than ambient because the inside of the cooler will have a temperature that is lower by about 5 – 10 °C depending on the prevailing climatic conditions. Produce also keeps longer because the inside of the cooler will have a high relative humidity and so produce will lose less water. In order to get the best out of the cooler it should be used properly.

The first requirement is to ensure that produce that is to be kept in the cooler is of good quality and is not damaged or diseased. This is important because damaged or diseased fruits will respire more and hence will be producing more heat than sound fruit. All produce that is to be stored in the cooler therefore needs to be graded first and all undesirable fruit discarded.

Careful handling of produce is needed and this includes keeping fruit on the shade. This is important because fruit exposed to direct sun will heat up and more energy will be required to get them cooler. In fact the fruit temperature if it is in the sun is actually higher than the ambient temperature. For example with a temperature of about 25 °C the fruit in direct sun will have surface temperature of up to 38°C. It is very important therefore to keep fruit in the shade at all times starting from harvest.

The cooler walls should be moistened before produce is put in. If the walls are not already wet then wetting can be about 20 minutes before loading to allow time for the temperature to start dropping. The door should be kept closed as much as possible so as to prevent the interior from warming up. Loading should therefore be quick and the door closed as soon as possible after the completion of the loading operation. The same principle also applies during storage. The door should be kept closed at all times so as to keep the interior as cool as possible.

Produce should be carefully loaded into the cooler. It is usually a good idea to start by placing boxes

against the walls about 10 cm away from the wall and to fill the cooler systematically in rows starting from the bottom going upwards. A small space should be left between the rows (about 5 – 10 cm) to allow for air circulation. Boxes should be stacked against all four sides since the area closer to the wall will be cooler.

The wetting cycle should be followed continuously as long as produce is being kept in the cooler. Inspection of the charcoal will show if it is moist as wet charcoal has a shiny appearance. The quantity of water should be enough to wet the charcoal and it is not necessary to reach the point of dripping. Care should be taken that the fruit are not splashed during wetting of walls. The temperature should be monitored at all times so that a record of the holding temperature of the produce is kept and known. Recording the temperature two to three times a day is useful and a maximum-minimum thermometer is also useful in keeping track of conditions in the cooler.

## 1.9. Materials

The list of materials is only a guide and it is advisable to order a greater quantity of materials since some may need to be discarded. Some pieces of timber for example may have knots or splits that may have to be cut out.

Each cooler requires approximately the following:

### 1. Timber

#### a) Poles with about 100 mm diameter base and lengths of:

3.0 m length	3
2.5 m length	2

#### b) Sawn timber about 25 mm x 50 mm

1.5 m length	16
2.0 m “	8
1.2 m “	8

- c) Sawn timber about 50 mm x 50 mm (for the roof)
  - 2.4 m length                      4
  - 2.6 m length                      6
  
- 2. Wire netting/mesh (eg diamond weave with 1.5 – 2.5 cm holes) 0.9 m width x 40 m
  
- 3. Charcoal 12 x bags (90 kg size bags if used for grain)
  
- 4. Paint - Oil paint 5 litres
  - Wood treatment /Used engine oil 1 litre
  
- 5. Door – 0.9 m x 1.8 m
  
- 6. Plastic sheet – 2.0 m x 4.0 m
  
- 7. Nails
  - a) 8 & 6 cm long – 1.5 kg
  - b) 4 cm long – 3 kg
  
- 8. Roof tiles/ Grass thatch – for roof area of about 5m<sup>3</sup>.
  
- 9. Wooden pallets for the floor.



## **2. POST-HARVEST HANDLING AND TRANSPORT OF HORTICULTURAL PRODUCE**

### **2.1. Introduction**

A visit was made to two exporters of horticultural produce in Rwanda and discussions held with people involved in this sector. Preparation and packing of passion fruit for export was also observed. The main export crop under discussion being grown by ADAR clients are passion fruit which is a subtropical fruit and has a specialty market in Europe. Efforts to have these fruits exported as organically certified fruits are also being made. These fruits grow well in Rwanda and there is a thriving regional market for fresh and processed fruit.

### **2.2. Overview of Handling and Packing of Passion Fruit**

A number of problems were observed with the fruit during the grading and packing exercise. These problems are indicative of the handling and transport environment.

#### **2.2.1. The Grading Process.**

Some of the reasons for the rejection of fruit during grading and packing are as follows -

- a) Bruising - Many of the fruit showed signs of bruising because the peel had scuff marks and the waxy layer was peeling off in places. This is a sign of abrasion damage to the fruits which may have been caused by packing fruits in unsuitable containers. It was observed that the fruits were delivered in large polypropylene woven sacks (90 kg capacity if used for grain). These bags are unsuitable because they do not adequately protect the fruits. There is also the possibility that the abrasion could have taken place during transport if the bags were transported on vehicles used for other goods. Fruits in bags roll around during transit and this will result in further abrasion.
- b) Fruit Splitting - This was observed on several fruits and these fruit had to be rejected during the grading process. This is another indication of poor packaging and the use of oversized containers.

- c) The splitting and cracking of the fruits was most likely due to compression damage where fruit at the bottom of a container are squashed by the weight of fruit on top. The use of oversized containers is a major contributor to this problem. This problem also occurs with poorly shaped containers such as baskets which are tapering ( the bottom is narrower than the top) and so fruit at the bottom of the basket are supporting a much greater load.
- d) Green Fruit – Some of the fruit that were rejected during the grading exercise were green or had little purple coloration of the peel. This is an indication of poor selection during the harvesting process and inexperienced harvesters. These fruits are undermature and they will not ripen properly even under ideal conditions. This problem may also be caused by growers trying to increase the number of fruit that they have for sale.
- e) Diseased Fruit – This was a major reason for rejecting fruit with *Alternaria* and *Septoria* as the most prevalent diseases. The presence of disease on fruit is a pre-harvest problem that results in fruits being rejected during grading and packing and so the exporter loses in terms of quantity exported. The other concern is that the potential for clean fruit to develop diseases during storage and shipping is high and this may result in rejects when the fruit is received by the importer.
- f) Over ripe Fruit – Some of the fruits had already started to soften and show signs of wrinkling. These fruits were classified as over ripe and were rejected. This problem is an indication of poor storage conditions where it is most likely the fruit were in an environment with poor ventilation and the temperatures were not very low. Ventilation is important because ripening volatiles need to be removed from the storage atmosphere. These will build up and spoil fruit that are still sound, for example ethylene can trigger a ripening response in mature fruit that would have otherwise kept for several days. Temperature control is the most important post-harvest treatment that can be used and if fruit are held at ambient the storage life is limited whereas fruit at a lower temperature will keep for a longer period.
- g) Scars – Scars on the surface of the fruit sometimes develop during the growth of the fruit. These scars can be caused by insect damage or by rubbing against a branch. If more than 10% of the fruit surface is scarred then the fruit is rejected. This is another problem that is caused by pre-harvest conditions but affects the total volumes of fruit that can be exported.
- h) Small Fruit – Fruit that were smaller than ca. 40 mm were rejected. Fruit size is influenced by

growing conditions and some of the fruit delivered were too small. This criterion of fruits does not affect post-harvest handling except to reduce the numbers of fruit exported.

### **2.2.2. Grading and Packing Facilities.**

The grading and packing exercise resulted in an overall packout of about 40%. This is not an unusual figure but it does mean that the packout facilities should be designed to handle large volumes of produce. The absence of a cool environment means that the produce can not be kept for a long time and needs to be handled speedily. The environment observed was that of packing under ambient conditions with a roof and concrete floor. The grading process was a manual system that involved selecting fruit onto a table which were then packed into export cartons. A number of observations made during the grading exercise include –

- a) Multiple grading decisions. This can slow down the grading process, especially if staff are not well trained.
- b) Grading height. This is important for worker comfort and can speed up the grading process if fruit that are being selected are at a comfortable height. The good fruit should be placed in a separate bin also at a comfortable height.
- c) Grading waste. The grading and packing exercise included a process of trimming the stems of passion fruit. This resulted in a lot of debris on the grading floor with the danger of some reaching the boxes of packed fruit.

### **2.2.3. Transport and Packaging.**

Fruit are transported to the collection point in various containers that the farmers may have. Some of the containers seen were large woven plastic bags and also plastic buckets and plastic baskets. Some of the problems that arise are that bags are not rigid and so do not protect the fruit. The plastic buckets are rigid but do not allow any ventilation. Some of the plastic baskets were too deep and this can result in fruit at the bottom being crushed. Some fruit were kept in smaller plastic bags and condensation was observed inside the bags.

This was probably caused by the high respiration rates of the fruit held at high ambient temperatures. These bags were sealed and the plastic acted as a vapour barrier. There is danger of accelerated disease and decay under such conditions.

Transport is a major problem since most of the fruit producers are resource poor farmers and so they will either use public transport or carry produce on foot. Some of the fruits were collected by truck. Some of the roads are not surfaced and therefore there is the danger of damage to fruits during transportation. The trucks used for transporting produce are not specially designated for this purpose but are also used for other activities.

### **2.3. Recommendations for Improvement in Handling, Grading, Transport and Packaging**

The problems that have been observed should be remedied so that exporters can experience increased viability and can supply a high quality product to the market. It is also important to note that many importers prefer to work with suppliers who are consistent in terms of volumes and quality.

The Grading process

- a) The grading process needs to be speeded up and this can be done by the delivery of better quality fruit. The quality of fruit coming from the field therefore needs to be improved. Several steps can be taken including harvesting of fruit at the correct stage of maturity. Growers need to be encouraged to select fruit at the proper colour and one way of doing this is to train those harvesting the fruit. Fruit that is not yet mature but is severely diseased should be harvested into separate containers and discarded.

During harvesting fruit should be kept in shade at all times. If fruit are collected at the end of each row then the container should be placed in a shady spot. During transportation the container holding the fruit should be covered with a moist material e.g. hessian or cloth.

In order to reduce bruising and scarring of fruit during growth, a good training and trellising system must be used. The poles used in the training system should have all branches and twigs coming off them removed so that they are smooth and there are no points that can damage or pierce the fruit.

The vines should be trained so that they hang freely from the trellis instead of all the vines getting entangled at one spot on the trellis.

Good disease control during the growth of plant in the field is very important for getting good yields but this also means less rejects during grading and packing.

- b) The second suggestion for improving the grading process is that of improved packaging for transporting the fruit from the field to the packhouse. The ideal type of package is a rigid container that allows plenty of ventilation. The container should not be too deep. A sample of a wood crate developed by Urwibutso de Nyirangarama staff was assessed and it is a good crate that will not damage fruit during transit.
- c) A common practice carried out in other regions is to carryout some pregrading before the actual exercise. This can be done in the field during harvesting. The grower can first go through the planting to select only the best fruit and can then make a second pass to select mature fruit that may have some blemishes. This field grading can be used for separating fruit into uniform colour and maturity. Another possibility is to grade the fruit on arrival at the collection centre. This has the advantage that fruit destined for other uses e.g. processing is selected at this point.

### ***2.3.1. Grading and Packing Facilities***

Many of the operations visited are still small and are just getting started. However the principles of grading remain the same irrespective of size. The grading exercise needs to be made efficient so that a large quantity of produce can be processed.

- a) One key requirement for this is that the grading staff are comfortable. The height of the grading table is important because staff should not have to bend over or reach over excessively as they will quickly tire and their output will be reduced.
- b) The next requirement is for a clearly demarcated storage area for the produce before it is graded. This area should be well ventilated but must protect the fruits from the environment. The storage area should also be well drained. The grading area and the storage area should not be exposed to combustion fumes such as from wood smoke or engine fumes. Any fumes such as engine fumes

should blow away from the area (hence the need for good ventilation). The storage area can be as simple as a room set aside for the purpose, but it should meet the above criteria.

- c) The grading and storage areas should be clean and easy to clean and a routine cleaning regime must be implemented. This will become more important as volumes increase. During the grading process a lot of waste is generated and specific containers for waste are needed and the floors and tables must be cleaned or swept frequently.

### ***2.3.2. Transport and Packaging***

There are two stages where transport is required , the first being from the field to the packhouse. This stage usually involves bulky loads and the main requirement is to reduce damage to the fruit. The use of improved containers like wood crates that are not too deep (e.g. up to 30 cm depth is acceptable) and allow ventilation is recommended for small round fruit such as passion fruit. Bananas can be transported while still in bunches as is the normal practice but they will benefit from padding (e.g. using banana leaves) added to the floor of a vehicle so as reduce bruising.

It is also important to note that containers should be kept clean. Cleaning can be as simple as dry brushing on a daily basis. Containers must not be used for other goods such as chickens and they must not be stored where livestock waste accumulates because they will become contaminated with manure and dirt!

The second transport phase is from the packhouse to the airport or other shipping point. The main requirement at this point is to keep produce as cool as possible. The vehicles used to transport produce should be parked in the shade before loading so that they do not heat up. The use of canvas as a cover for the back of a truck is a good idea as it does not heat up as much as metal and it usually allows some ventilation.

## ANNEXES

## **ANNEX I. NOTES FROM VISITS TO COOLER CONSTRUCTION SITES**

Charcoal Evaporative Coolers were constructed at four locations in Rwanda during the period of the consultancy. The sites belong to some of ADAR's clients who are involved in export horticulture. The clients were met on the first day and the concept of the Evaporative Cooler was introduced and the expected performance and potential uses were discussed. It was agreed that ADAR would provide certain materials including the wire net\mesh, timber, plastic sheet (for the roof), nails, paint, used engine oil. The clients would provide charcoal, roofing material (i.e. grass thatch), the carpenter and labour.

### **Site 1. Nyirangarama. (3, 5, 6, 13 June, 2002)**

This is where Gerard Sina (who is involved in export of passion fruit) has his main operation. The passion fruit are purchased from smallholder farmers in the area. The crop is delivered to the site and it is then graded and packed for export. Non-export grade fruit is used for juice production. An Evaporative Cooler on this site can be used to store fruit and keep it fresh for a longer period. It can be used for bulking up produce before shipping to market.

Discussions were held with the owners and a site for the construction of the cooler was agreed. The site that was selected for the cooler is a sheltered site in a field across from the main buildings. The site was exposed to wind movement although a wind break is in place to protect from strong winds. The site has plenty of water which is very important for the operation of the Evaporative Cooler. The site is accessible for those delivering produce and it is also on a gentle slope so drainage is good. The site was prepared by clearing the area of grass and other plants leaving bare ground that was compacted.

The owner offered to purchase the required timber and roofing material as well as the other materials as per original agreement. Discussions were held with one of his carpenters on the design and construction of the cooler and during these discussions a number of modifications to the original design were agreed. These included the change from a separate timber frame for the charcoal wall to having the timber supports attached directly to the poles for the main frame. The use of clay tiles for the roof was also discussed and it was agreed to use grass (*Eragrostis* spp) as roofing material. In order to further protect the roof from heavy rainfall it was suggested that the plastic sheet be immediately under the grass with a layer of plywood underneath. Mr. Sina's carpenter also suggested putting a layer of small stones at the bottom of the charcoal wall as a means of improving drainage. He also said he would use clay tiles for the floor.



Construction of the cooler started on 5 June with the marking and digging of the holes for Eucalyptus poles of the frame. The holes were dug until the subsoil was reached which was about 55 - 60 cm. The frame was put in the same day and the carpenter started nailing the wood strips to the poles. The carpenter had three people helping and he estimated it would take about three days to complete the structure. On the second day the main activity was the attachment of the wire fencing to the timber frame after the paint was allowed to dry.

Construction was completed by the fourth day with only the filling with charcoal to be done. More charcoal was purchased as the initial estimate was inadequate and a total of 10 bags were used. A skirting made from bricks was put around the edges of the cooler and a fence was erected around the site to improve the security of the cooler. Mr. Sina's staff wetted the charcoal thoroughly for two days and they observed that more water was needed initially with the amount declining later. This could be due to washing out of finer particles from the charcoal during the initial wetting cycle. On the day of testing the walls had been wetted around 7 am and temperatures were tested around 10 am. The temperature in the Evaporative Cooler was measured by placing a thermometer in the cooler with the door closed for about 20 minutes before taking the reading. The recorded temperatures were -

Cooler : 18 °C

Outside (in the shade): 25 °C

This indicates that the cooler does reduce the temperature and should be effective in reducing deterioration of fresh produce. A maximum-minimum thermometer was delivered to Nyirangarama and further testing of the cooler was discussed, and a format for evaluation was agreed (see "Guidelines for Testing Effectiveness of Evaporative Cooler" in appendix). Mr. Sina's staff had placed five crates of fruit in the cooler to get an indication on the performance of the cooler.

## **Site 2. Butare ( 7, 11, 14, and 19 June, 2002)**

The cooler in Butare was constructed on the National University of Rwanda farm at Tonga. This cooler construction was under the auspices of the Faculty of Agronomy and PEARL (University Outreach) who are in the process of rehabilitating the university farm and putting in a horticultural section. The cooler will be used for training and demonstration purposes but will also be used for holding produce from the field.

The initial visit was to meet staff of PEARL and the Faculty of Agronomy and discuss the concept of evaporative cooling and its potential uses. The idea was found to be favourable and PEARL agreed to purchase material for the construction of the cooler. A visit to the site was also made. The area is on a slope so drainage is good and it also experiences a light breeze which is an important consideration in site selection. A second visit was made to discuss the requirements for the construction. Extensive discussions were held with the carpenter about the design and photographs from the construction at Nyirangarama proved useful in demonstrating the different steps. A decision was made to use tiles for the roof at this site and so the dimensions were adjusted for this with the height of the roof at the front being 2.6 m and the rear 2.0 m.

The progress on this site was steady with the timber frame being completed by the end of the second day after commencing construction. The walls were filled with charcoal when the final visit was made but the roof was not yet completed as they were waiting delivery of the tiles. A decision to use cement for the floor was made and this was to be done within a few days together with the installation of the door. During the final discussions it was agreed that possible modifications could be to raise the height of the wall by using plywood sheeting between the charcoal wall and roof (leaving a gap of 20 cm to the roof). This would block off the upper space left by the steeper angle of the tile roof and encourage air movement through the charcoal walls. Since water application to the wall would be manual it was decided that raising the height of the charcoal portion of the wall would make water application more difficult and so plywood was used instead. A maximum-minimum thermometer and a sample recording sheet was handed over to Faculty of Agronomy staff for their use during trials and demonstrations.

### Site 3. Kinamba ( 8, 10, 11, 13, and 18 June, 2002)

Kinamba is an area in central Kigali and the site belongs to Mrs Donatille Nibagwire who runs Floris (S.a.r.l.). This is a company that is involved in the export of banana, passion fruit, avocado, and pineapple to Europe. It is expected that the cooler will be used to hold fruit as it comes in before export. The Evaporative Cooler should provide a cooler, moister environment that should slow down the rate of ripening.

The site is on the Floris premises next to a stream but on a raised piece of ground where a shed or packhouse may be constructed in the future. There is good aeration and it is very accessible for delivery of produce. Mrs Nibagwire indicated that a supply of water is not a problem on this site. Timber was purchased from nearby dealers and construction started immediately after the carpenter had understood what was needed to be done. This site also chose to use clay tiles for the roof (to be obtained from Nyirangarama) and so the height measurements were the same as for Butare. A cement floor will be put into the cooler. Construction of the wood frame (including painting) was completed on the first day. The carpenter had three workers who were helping in the construction.

Installation of the fence started on the second day after they had put in the cooler door. Corrections were made after it was observed that the inner wire fence was not properly attached to the corner poles. An important observation is that fencing is a time consuming operation, and the wire should be pulled tightly so that the wall does not sag when filled with charcoal. It was interesting to note that Floris staff had started fencing off the area to be used for produce handling which is an indication that security is a concern at this location. The wire mesh for the double walls was in place by the fourth day and the filling of the walls with charcoal had started. It was observed that the original estimate for charcoal was not adequate and more had to be obtained. Filling the walls must be conducted in a manner which prevents compacting the charcoal so as to ensure good air flow through the walls. The carpenter had finished working on the timber frame for the roof but it was not completed since the tiles had not arrived from Nyirangarama. The tiles for the roof were put in place a week after construction started.

The charcoal walls were tested by applying 40 litres water twice on the sixth day. It was observed that there was excess runoff and so it was decided to use less water per application during operation. A maximum-minimum thermometer and a Recording Sheet were delivered to Mrs Nibagwire of Floris so that the performance of the cooler could be evaluated.

A cement floor will need be put in by Floris as they had indicated but a pallet should also be used on top of the floor. It was suggested that the charcoal walls could be raised so that there is a 20 cm gap between the top of the walls and the roof. This extra height was made necessary because the tile roof is higher than that in the original plans where grass thatching was used in place of tiles.

#### **Site 4. Kibungo (12 and 15 June, 2002)**

This site, to the east of Kigali, is where Emballage Rwanda has its banana production with several hundred outgrowers supplying the company with fruit that is then packed for export. The cooler will most likely be used to store fruit that has been delivered by outgrowers. The Emballage Rwanda premises are at Gatore, a small business centre, and the cooler was built at the rear of the offices. The site has adequate ventilation and the ground was already clear and so erection of the cooler could start without any special land preparation.

The procedure for the construction was discussed with the carpenter and again the use of photographs made explanations easier. Material purchased by ADAR was handed over including the paint, wire netting, nails and plastic sheet. The sawn timber was also delivered as it was purchased in Kibungo en route to Gatore. Emballage Rwanda staff indicated they would obtain eucalyptus poles as they were abundant in area. During discussions on what to use for the roof a suggestion was made that a local alternative was roofing material made from banana stems. It was agreed that this was a good idea since this type of roof can provide a cool shade and it was readily available. Progress at his site was steady and by the visit on the 15th the carpenter had almost completed the timber frame but he indicated he needed more timber, mainly for the roof. This is an indication that the list of materials should serve only as guide and it is recommended to buy more than is provided on the list.

Since it was not possible to visit this site within the remaining time frame, final discussions were held on work for the completion of the cooler including advising the carpenter to pull the wire tightly. The door was still to be delivered by Emballage Rwanda to the site and this would come together with the extra timber. The use of cement for the floor was agreed and a suggestion was made that a drainage channel could be put in to draw water away from the cooler. The use of the cooler was discussed along with possible modifications to improve performance.

## **ANNEX II: GUIDELINES FOR TESTING EFFECTIVENESS OF EVAPORATIVE COOLER**

### **Introduction**

The Evaporative Cooler is designed to lower air temperature when the charcoal wall is moistened. Air moving across the charcoal wall picks up moisture and its temperature is lowered and hence the inside of the structure becomes cooler and produce that is kept in it will keep for a longer period. In order to find out if the Charcoal Evaporative Cooler is operating effectively a series of tests may be carried out. These tests may also be used to determine if changes to the operation or design of the cooler are effective. For example the operator may wish to increase the rate of water application to the charcoal wall and will need to know if the changes are effective. In addition these tests can be used to determine if coolers are achieving their potential.

### **Testing Methodology**

**Two simple tests may be carried out and these are:**

a) **Fruit or Vegetable Response Tests.**

These tests are based upon the condition of the product being stored as a way of measuring the efficiency of the cooler. The fresh produce should keep for a longer period before showing signs of deteriorating if the cooler is working well.

1. Apply water to all the charcoal walls. The walls should be fully moistened and water should be just at the point dripping from the bottom. The cooler walls should be moistened at least once every two hours (day time only) throughout the duration of the test.
2. Place 3 to 4 crates of freshly harvested and uniform (especially maturity) fruit or other fresh produce in the cooler.
3. Place 3 to 4 crates of freshly harvested and uniform fruit (or other fresh produce) in a separate storage area which is not exposed to direct sunlight.

4. Record observations on the condition of the fruit/fresh produce in the cooler and in the room on a daily basis and make a note of the following :

- I)      Shriveling or wilting
- II)     Skin colour
- III)    Diseases
- IV)    Any other signs of deterioration

### Fruit Response Test : Recording Sheet

Test/Trial

Location \_\_\_\_\_

Date\_\_\_\_\_

[illegible]

Comments:

## **Temperature Response Tests.**

These are designed to measure the change in temperature and humidity inside the cooler and compare them with ambient conditions.

1. Apply water to all the charcoal walls. The wall should be fully moistened and water should be just at the point dripping from the bottom.
2. Ensure door is closed and wait for twenty (20) minutes before recording the temperature and humidity:
  - I) Inside the cooler and
  - II) Outside the cooler (in the shade).
3. The temperature and humidity can be recorded after one hour and at regular intervals (e.g. every two hours during the day) as needed.
4. Temperature should be recorded using a good quality glass thermometer or digital temperature probe.
5. Humidity can be measured using a wet bulb thermometer or whirling hygrometer or a digital hygrometer.



## Temperature Response Test : Recording Sheet

Test/Trial \_\_\_\_\_

Location \_\_\_\_\_

Date \_\_\_\_\_

Test No.	Time	Evaporative Cooler		Outside	
		Temp (°C)	Humidity (%)	Temp (°C)	Humidity (%)

Comments:

### ANNEX III: PHOTOGRAPHS OF COOLERS UNDER CONSTRUCTION



**Photograph 1.** Timber Frame Under Intersection of Wood Strips



**Photograph 2:** Notching in Wood for Construction (Note parallel wood strips)



**Photograph 3.** Supporting Piece of Wood Prevent Wood From Warping Wall



**Photograph 4.** Timber Frame For Charcoal To (note painting of wood)



**Photograph 5.** Timber Frame For Charcoal Completed And Wire Netting Attached



**Photograph 6.** Filling In Walls With Wall Charcoal



**Photograph 7.** Filling In Walls With Charcoal (Note grass roof)



**Photograph 8.** Completed Charcoal Evaporative Cooler (Side View)





Photographs 9 & 10. View of Charcoal Wall



## **ANNEX IV: POTENTIAL TEMPERATURE AND RELATIVE HUMIDITY CONDITIONS INSIDE COOLERS**

The decision to build a cooler should be based on the prevailing climatic conditions as these determine the potential temperature drop that can be achieved. The normal indicator is the “wet bulb” temperature. This shows how low the temperature in a cooler can go because Evaporative Coolers cool down to the wet bulb temperature. The greater the difference between the dry bulb and the wet bulb temperatures the more effective a cooler will be. Climatic or meteorological records should therefore be studied so as to work out where to place coolers and the lowest temperatures that can be achieved.

Where meteorological records are not available, the use of humidity data and temperature data can still be used to work out the potential benefit of an Evaporative Cooler. This is carried out by using Psychrometric charts which indicate the relationship between the different temperature and water vapour properties of air.

A sample Psychrometric chart is included in this annex. The important points to note on the chart are:

- a) Wet bulb temperature. This is the temperature of a thermometer with wet/moistened material or wick around it. It is the measurement of the temperature of air saturated with water vapour. The wet bulb temperatures are the diagonal lines running upwards from right to left on the chart.
- b) Dry bulb temperature. This is the normal measurement of temperature using a thermometer or other instrument. The horizontal scale on the chart is the dry bulb temperature.
- c) Relative Humidity. This is an indication of the amount of water in air. The water content of air is usually expressed as a ratio between the water content of air to the maximum water content that can be held at that temperature. It is important to note that the water holding capacity of air increases as the temperature of the air increases. Relative humidity is the upwardly curving line on the chart.

Knowledge of any two of the above can be used to work out the other. Where weather records provide the temperature and humidity data then the wet bulb temperature can be worked out.

The point where the relative humidity and dry bulb temperature cross is the actual condition of the air or the starting point. If this air is passed through an Evaporative Cooler (i.e. moisture is added to the air without adding heat) then the temperature of that air is cooled and the temperature follows the wet bulb line from the starting point up to the 100 % relative humidity line. This then gives the reading of the new air temperature and this will be the temperature of the Evaporative Cooler. In practice the temperature of the Evaporative Cooler will be one or two degrees above the wet bulb temperature due to inefficiencies in cooling.

It can therefore be seen that potential for evaporative cooling is influenced by relative humidity. In other words, the lower the ambient relative humidity the greater the potential for evaporative cooling and the greater the temperature drop. Evaporative cooling efficiency will therefore vary from season to season and from one locality to another. Some examples of potential cooler temperatures calculated using relative humidity and dry bulb records for Karama (the meteorological station close to Kigali) in Rwanda are shown below. These show the potential for evaporative cooling. Actual cooler efficiencies may be different because of localized climatic variations.

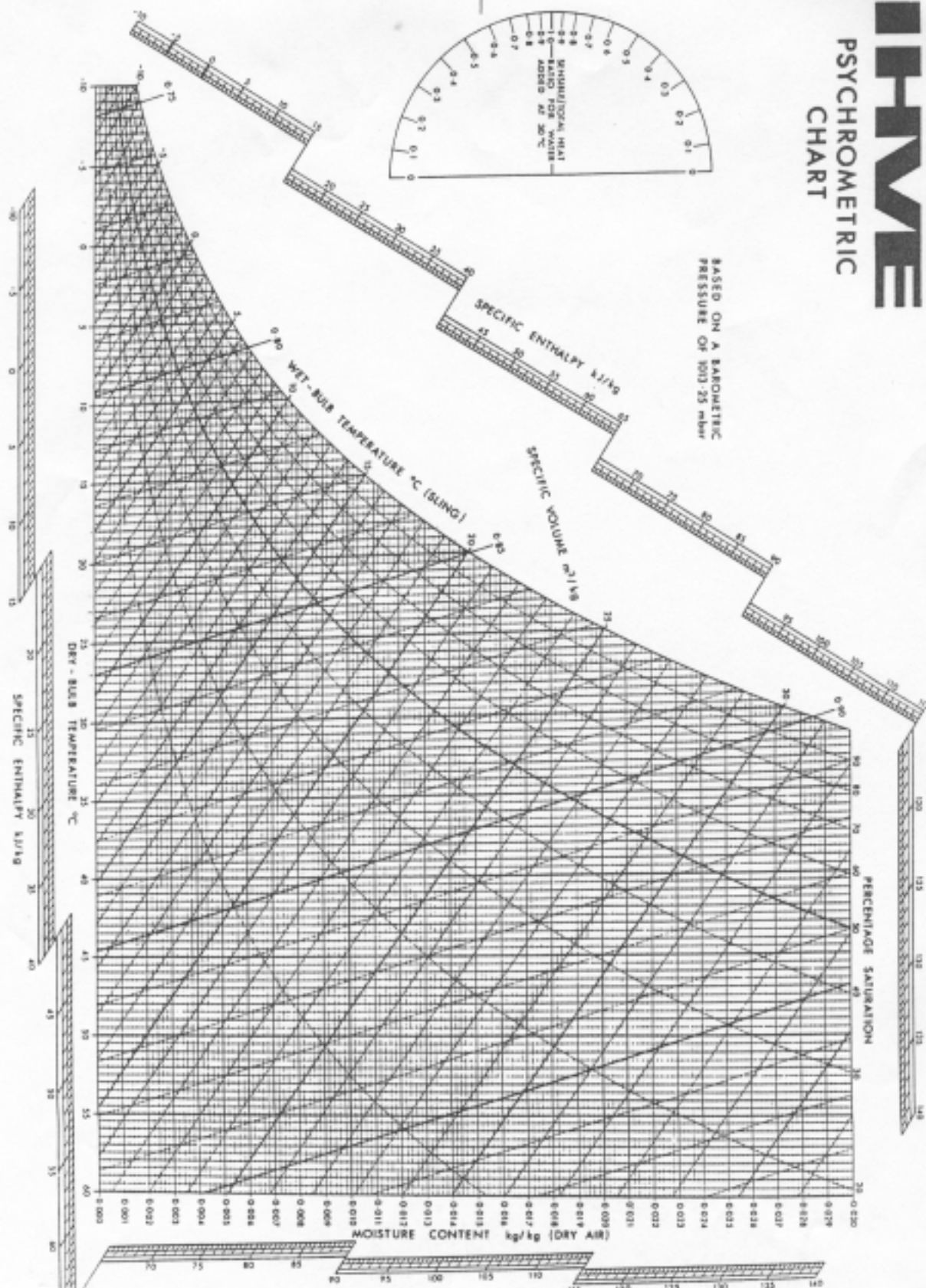
#### **Influence of Season on Potential Temperatures for Evaporative Coolers at Karama**

<b>Time</b>	<b>Dry bulb Temp (°C)*</b>	<b>Relative Humidity (%)*</b>	<b>Wet bulb Temp (°C) (potential temperature inside cooler)</b>
<b>Month: April</b>			
8:00 am	18.5	87	16.5
10:00 am	22.0	73	18.5
12:00 noon	24.0	64	19.5
2:00 pm	24.2	63	19.3
4:00 pm	23.5	67	19.5
<b>Month: August</b>			
8:00 am	18.2	68	14.5
10:00 am	23.0	46	15.5
12:00 noon	25.8	37	16.5
2:00 pm	27.0	35	17
4:00 pm	26.5	37	17

(\* Data extrapolated from C. Van Minnen Bruggen, Geography of Rwanda)

# IHVE PSYCHROMETRIC CHART

BASED ON A BAROMETRIC  
PRESSURE OF 1013.25 mbar



## **ANNEX V: SUGGESTIONS FOR MODIFICATIONS OF/ADDITIONS TO THE COOLERS**

### **I. Wind Driven Ventilators**

There are various modifications that can be made to Evaporative Coolers so as to improve their efficiency. One method is to improve air flow: if more air flows across the charcoal walls then the interior of the cooler will become cooler faster and more air will move through produce being kept in the store hence cooling the produce more efficiently. Air flow can be improved by installing a wind driven ventilator on the roof of the cooler. This ventilator works on the principle that when it is turned by wind, it will suck warm air which has risen to the top of the cooler to the outside, therefore drawing new air in through the wet charcoal walls (cooling same in the process). Coolers with ventilators will have a higher rate of air movement than those relying on wind alone. An example of a wind driven ventilator is shown in the diagram below. The ventilators being suggested for use in Evaporative Coolers are similar to those used in large buildings to provide good ventilation but since they require no electricity to function, they are inexpensive to run; moreover they can be used in remote locations with no electricity supply.

### **II. Water Reservoir with Drip Tube**

One of the major activities to ensure the efficacy of the cooler will be the wetting of the charcoal walls. This operation can be simply carried out by hand with someone pouring water from a container over the top of the charcoal wall. Alternatively the source of water can be a hose pipe. This can turn out to be labour intensive if it needs to be repeated several times a day. One possibility for reducing this labour requirement is to fill a container and place it on top of the cooler, with a pipe leading from the container to deliver water to the top of the charcoal walls. If this pipe is perforated so that it lets water out as a small trickle then the charcoal walls can be kept moist over a long period. An example of such a setup is shown in the diagram below. The exact size of the water tank and the number of small holes in the perforated pipe will need to be worked out.

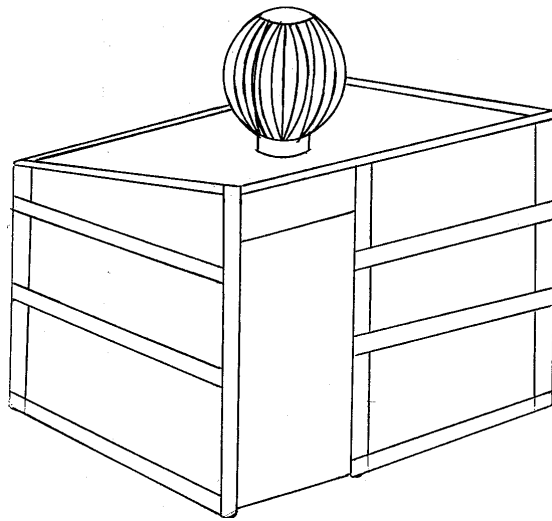
One possible approach would be to first put in four small holes spaced 20 to 30 cm apart. This pipe is then attached to a 20 litre container filled with water and placed on the roof. The time taken for the water container to empty should then be recorded. Observations on any excess water dripping from the bottom of the wall should be made.



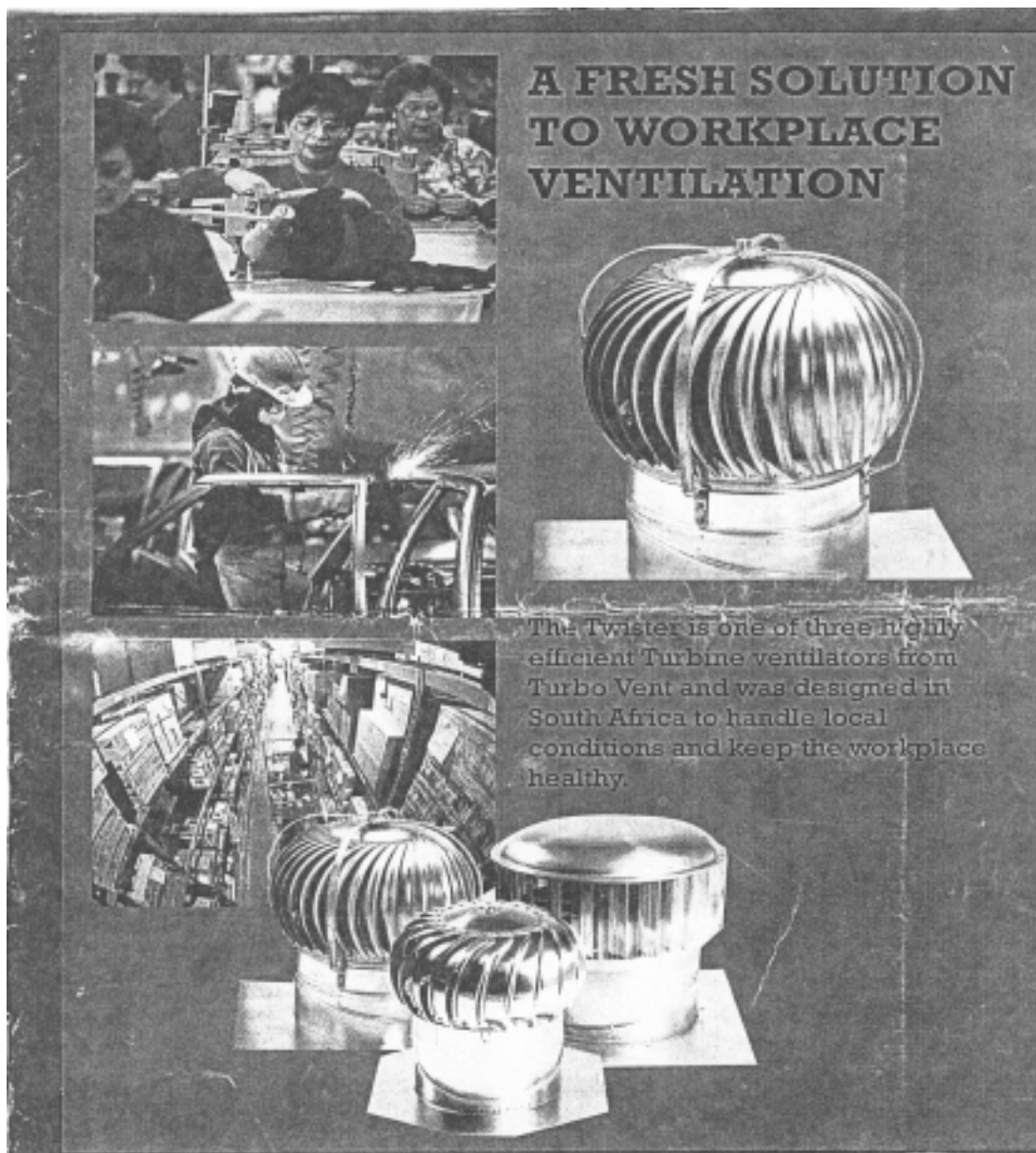
The operator can then modify the system to improve its efficiency by a) increasing the number of holes in the pipe if the wall is not wetted throughout, b) increasing the size of the water tank if it empties too quickly and c) reducing the number of holes if the wall is too wet and excess water runs from the bottom.

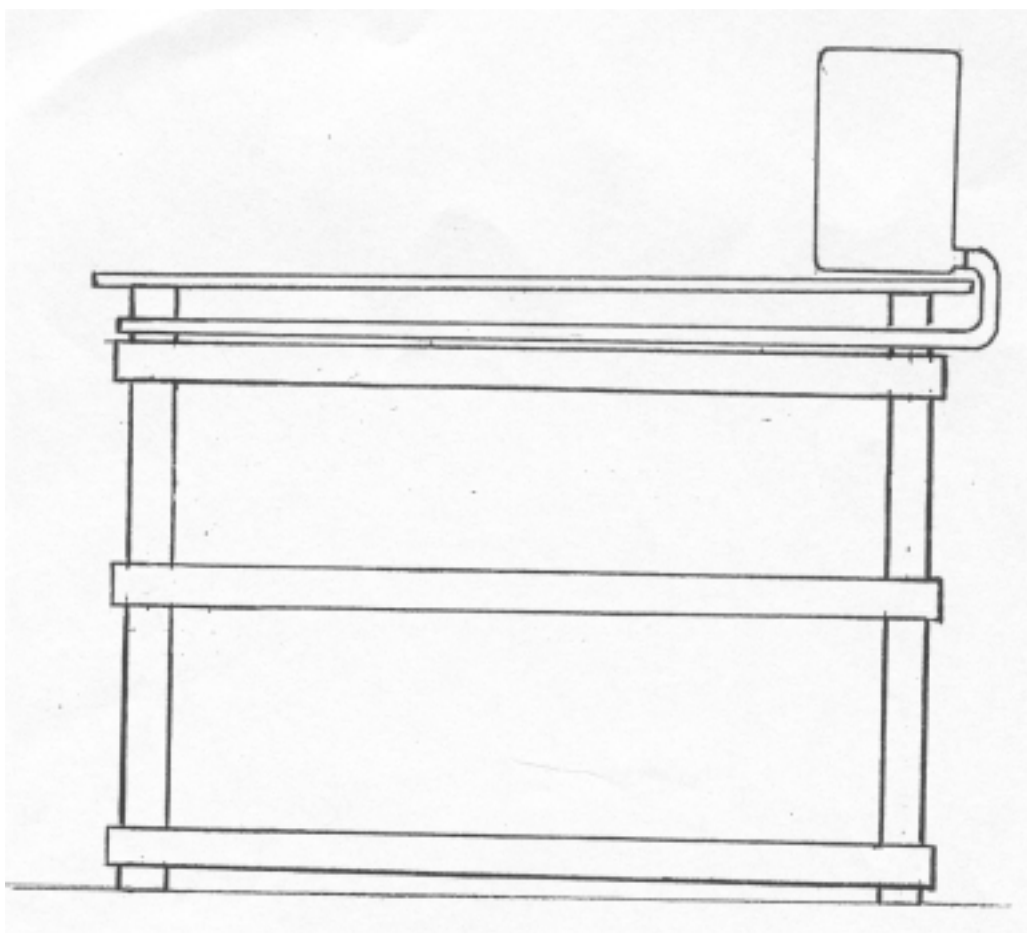
### **III. Size of Cooler**

The size of the Evaporative Cooler used in this report is adequate for use under conditions of natural ventilation. If a larger cooler is desired it may be possible to increase the length of the cooler to 4.0 m and the width to 2.0 m as long as the long side is facing the prevailing wind. This will ensure that there is adequate ventilation across the charcoal wall. It is also possible to construct larger Evaporative Coolers if motorized fans are used to force air circulation. For these larger Evaporative Coolers, electricity must be available in order to drive the fans. The size of the coolers will depend on the capacity of the fans which should provide an air flow rate of at least 25 – 50 m<sup>3</sup>/minute. It is advisable however to have the smaller “appropriate technology” Evaporative Coolers in the field for storing produce and removing field heat soon after harvest. At the major collection centers it is advisable to have proper cold stores which have a higher cooling capacity.



**Diagram 7: Modification to Charcoal Cooler – Wind Driven Ventilator Mounted on Roof**





**Diagram 8. Modification to Cooler – Water Reservoir with Perforated pipe on top of charcoal wall**